

REVIEW ARTICLE

# Is Anesthesia Dangerous?

André Gottschalk, Hugo Van Aken, Michael Zenz, Thomas Standl

## SUMMARY

**Background:** Recent years have seen a rise in overall anesthesia-related mortality.

**Method:** Selective review of the literature.

**Results:** Anesthesia-related mortality has fallen from 6.4/10 000 in the 1940s to 0.4/100 000 at present, largely because of the introduction of safety standards and improved training. The current figure of 0.4/100 000 applies to patients without major systemic disease; mortality is higher among patients with severe accompanying illnesses, yet in this group, too, perioperative mortality can be reduced by appropriate anesthetic management. Moreover, the use of regional anesthesia can also improve the outcome of major surgery.

**Conclusion:** A recent increase in the percentage of older and multimorbid patients among persons undergoing surgery, along with the advent of newer types of operation that would have been unthinkable in the past, has led to an apparent rise in anesthesia-associated mortality, even though the quality of anesthesiological care is no worse now than in the past. On the contrary, in recent years, better anesthetic management has evidently played an important role in improving surgical outcomes.

► **Cite this as:**

Gottschalk A, Van Aken H, Zenz M, Standl T: Is anesthesia dangerous? *Dtsch Arztebl Int* 2011; 108(27): 469–74. DOI: 10.3238/arztebl.2011.0469

There should be no deaths due to anaesthesia [sic] (Sir Robert Macintosh, 1949) (1).

These were the poignant words used by the first holder of a chair in anesthesiology in Europe, Sir Robert Macintosh, some 60 years ago, in order to emphasize that administering anesthesia is always dangerous and for this reason should be undertaken only by physicians with specialist qualifications (1). A study conducted in 1948 to 1952 in 10 university hospitals in the US confirmed the assessment of the riskiness of anesthesia in Macintosh's lifetime (e1). In 599 500 patients, the study found that anesthesia-associated mortality (*Box 1*) was 64/100 000 operations. Extrapolated to the population this means a death rate of 3.3/100 000. In the following decades, new techniques and monitoring options were developed, and anesthesiologists received better training, so that the death rate was reduced. In the early 1940s, anesthesia-associated mortality was estimated to be 1/1000, and in the 1960s it was still high, at 0.8/1000 (e2); the 1970s and early 1980s saw a reduction to 10 to 30/100 000 (e3, e4). Data collected between 1965 and 1969 had shown a dramatic increase in perioperative mortality in emergency patients and patients with severe comorbidities (ASA classes 3 to 5, *Table 1*) (e2).

In tandem with the introduction of extended safety standards—for example, pulse oximetry and capnometry—a further relevant reduction in anesthesia-related mortality was achieved (*Box 1*). At the end of the 1980s, the death rate was merely 0.4/100 000 anesthetic procedures (2, e5).

## Anesthesia and mortality today

According to a calculation based on data from 56 member states of the World Health Organization (WHO), some 230 million major surgical procedures are being carried out under anesthesia worldwide every year (3). In the industrialized nations, the estimated perioperative complication rate is 3% to 16%; in 0.4% to 0.8% (about 1 million patients) of all cases the result is lasting damage or death (e6, e7). Two studies have investigated the role of anesthesia-associated deaths.

On the basis of the ICD-10 codes that relate to anesthesia-associated complications, the authors of an epidemiological study in the United States evaluated death certificates from the years 1999 to 2005 (4). In an estimated 105.7 million surgical cases, they found a total of 2211 anesthesia-related deaths and calculated an anesthesia-associated death rate of 8.2/1 000 000 hospital discharges. Of these deaths, 867 occurred in

Klinik für Anästhesiologie, Intensivmedizin und Schmerztherapie, Knappschafts Krankenhaus Bochum Langendreer, Universitätsklinikum der Ruhr-Universität Bochum: PD Dr. med. Gottschalk, MBA, Prof. Dr. med. Zenz

Klinik und Poliklinik für Anästhesiologie und operative Intensivmedizin, Universitätsklinikum Münster: Prof. Dr. med. Dr. h. c. Van Aken, FRCA, FANCZA

Klinik für Anästhesie, Operative Intensiv- und Palliativmedizin, Städtisches Klinikum Solingen gGmbH: Prof. Dr. med. Standl

BOX

## Definitions

- **Anesthesia-associated mortality:**
  - Mortality in the context of an operation that was performed under anesthesia (general or regional anesthesia). A causal association between the anesthesiological measures and the patient's death cannot be established, however. For these reasons, anesthesia-associated mortality is hard to measure, and the exact evaluation of anesthesia in the overall outcome is problematic.
- **Anesthesia-related mortality**
  - Mortality that is caused directly by anesthesiological measures.

hospital, 348 in outpatient settings, 46 on admission to hospital, 258 after discharge, and 349 in a hospice or nursing home. No specific details were reported for the remaining deaths.

The percentage proportions are as follows:

- 46.6% of all deaths were associated with an anesthesia overdose
- 42.5% of deaths were due to adverse effects of anesthetics that had been administered at therapeutic doses
- 3.6% of all deaths were associated with pregnancy/obstetric care.

Among the remaining complications (7.3%) that resulted in death were malignant hyperthermia (1%) and intubation problems (2.3%). Anesthesiological complications were stated as the cause of death in only 241 cases (2.2/1 000 000).

A European study published in 2006 used a different methodological approach (5). The investigators evaluated 537 459 death certificates from 1999. On the basis of ICD-9 they set out a list of codes that relate to anesthesiological care or anesthesia-associated complications. In addition, they used all codes that relate to complications after medical, gynecological, or surgical interventions. The death certificates were evaluated on the basis of this list. After identifying a total of 1491 deaths the study authors sent questionnaires to the issuers of the death certificates, so as to verify the influence of anesthesiological care. Among the deaths that were exclusively related to anesthesiological measures, they found a mortality rate of 0.69/100 000 and in those cases that were partly associated with anesthesia, of 4.7/100 000 cases. Furthermore, the results of the study showed an association between anesthesia-related deaths and patients' age or ASA status (Table 2).

A single-center study from the US investigated all perioperative deaths (within 24 h postoperatively) for a

period of 10 years (6). In 72 595 anesthetic procedures, 144 cases of perioperative cardiac arrest were reported. The risk rose with patients' increasing ASA status. Of these 144 cases, a total of 15 were declared to be anesthesia-associated; seven of these patients died. The causes of death were drug-related events, problems in respiratory management, and a myocardial infarction. The anesthesia-associated death rate was reported to be 5.5/100 000.

A Dutch case-control study investigated the risk factors of anesthesiological management relative to postoperative morbidity and mortality within 24 hours (7). An early study published by the same working group, which investigated 24-h postoperative mortality in 869 483 patients, the authors identified 807 deaths; 119 of these were anesthesia-associated deaths (e8). The 807 deaths were compared with 883 other cases in order to identify risk factors within anesthesiological management. The authors found a significantly reduced risk for the following constellations:

- Safety-checking the equipment using a checklist (odds ratio [OR] 0.64)
- Documentation of the equipment check (OR 0.61)
- Directly available anesthetist (OR 0.46)
- No change in anesthetist during the operation (OR 0.44)
- Presence of anesthesia nurse (full-time position) (OR 0.41)
- Two persons during emergence of anesthesia (OR 0.69)
- Antagonizing of muscle relaxants and/or opioids (OR 0.1 and 0.29).

Postoperative analgesia with opioids (OR 0.16), local anesthetics (OR 0.06), or a combination of opioids and local anesthetics (OR 0.325) were associated with a reduced risk of mortality compared with no analgesia.

In sum, anesthesia-related mortality in patients without relevant systemic disease is low, at 0.4/100 000. However, an increase in death rates was observed in patients with relevant comorbidities (ASA III: 27/100 000 and ASA IV: 55/100 000). Anesthesia-related mortality was 0.69/100 000. According to data from Germany's Federal Statistical Office, the proportion of patients older than 65 who had to undergo surgery rose from 2005 to 2009 from 38.8% (n = 4.7 million) to 40.9% (n = 5.9 million) of all operations (2005: n = 12.1 million, 2009: n = 14.4 million) in Germany (www.gbe-bund.de).

In conclusion: In purely numerical terms, anesthesia-associated mortality has risen again. The reason for this increase is not a decrease in the quality of anesthesiological care, but an increase in the proportion of elderly, often multimorbid, patients undergoing surgery. The reasons are:

- Surgery is much more common among such patients nowadays; in the past the multimorbidity would have posed an insurmountable obstacle.
- The number of previously unthinkable highly invasive operations has increased.

# Complications during general anesthesia

The risk of aspiration in the context of general anesthesia has been constant for decades, at 1 per 2000 to 3000; pregnant women after the second trimester have a higher risk of approximately 1/1000 (e9, e10). A recent study showed a decreasing incidence of aspiration in pregnant women (8). Fortunately the mortality of bronchopulmonary aspiration is low, and the dreaded acid-associated pneumonitis is rare (Mendelson syndrome [chemical pneumonitis, massive bronchospasm, severe disruption of gas exchange] 8%, mortality 3%).

The cricoid pressure taught thus far for emergency intubation is not likely to prevent aspiration. However, administration of antacids, H<sub>2</sub> antagonists, and proton pump inhibitors before intubation lowers the risk of aspirating gastric acid with a pH <2.5. This does not improve the outcome after aspiration, however (9).

According to what is currently known, relaxing the nil by mouth rule (clear fluids up to 2 hours before anesthesia is initiated) has not resulted in an increase in the risk of aspiration (e11).

Intraoperative awareness is still feared by many patients, which can lead to chronic psychological problems if a patient remembers intraoperative events (10). The risk for awareness is 0.1% to 0.15%, younger female patients and cardiac or obstetric surgery carry a higher risk, at 0.26% (e12, e13). The risk of developing long-term neuropsychological disorders in awareness patients is 10% to 33% (11). Awareness phenomena are perceived as less stressful in the absence of pain than awareness accompanied by an intense experience of pain (11). Sufficiently deep anesthesia and optimized use of muscle relaxants can help avoid awareness.

Muscle relaxants are an indispensable element of anesthesiological practice. They facilitate endotracheal intubation and improve surgical conditions in intra-abdominal and endoprosthetic procedures, especially in emergencies. Arbous et al. (7) have statistically calculated that lowering perioperative mortality by antagonizing of muscle relaxants can be achieved at the conclusion of surgery. This enables the indirect conclusion that Postoperative Residual Curarisation (PORC) probably has a negative effect on patients' outcomes. The risk for postoperative pulmonary complications correlates with:

- Increasing age
- Longer duration of surgery
- Intraabdominal surgery
- Use of the slow-release muscle relaxant pancuronium
- Deep muscle relaxation (12).

# Complications during regional anesthesia

Regional anesthesia has become increasingly important in recent years. In addition to regional anesthesia for surgery, postoperative regional anesthesia plays an important part, since it has been shown that continuous regional anesthetic procedures enable the most effective analgesia in the postoperative phase (13, e14).

TABLE 1

**Classification of the American Society of Anesthesiologists (ASA), which categorizes patients into different risk groups on the basis of pre-existing systemic disorders or their physical condition**

Class	Clinical picture
ASA I	Patient without systemic disease—for example, patients with fractures, localized infections
ASA II	Patient with mild systemic disease—for example, patients with dyspnea on exertion, moderate hypertension, or non-insulin dependent diabetes; smokers
ASA III	Patient with severe systemic disease—for example, patients with heart failure, angina pectoris, severe cardiac arrhythmias, respiratory failure, chronic renal failure
ASA IV	Patient with very severe systemic disease that is a constant threat to life—for example, severe decompensated heart failure, severe malignant hypertension, pronounced respiratory failure even at rest
ASA V	Moribund patient who is not likely to survive the next 24 hours without surgery/intervention
ASA VI	Patient with dissociated cerebral death who is an intended organ donor

In spite of this, in defining an indication for a regional anesthetic procedure, possible complications need to be borne in mind, such as neural damage, paraplegia after central neuraxial blockades, and infectious complications. Furthermore, a multitude of operations cannot be performed under regional anesthesia but require general anesthesia.

The most severe complication associated with central neuraxial anesthesia consists of persistent paraplegia. The incidence of 1 per 150 000 to 220 000 that was reported on the basis of retrospective studies seems too low in the light of more recent studies (e15, e16). A study of more than 1.7 million patients found an incidence rate of 1/200 000 for epidural hematoma in the obstetric setting and 1/3600 for orthopedic procedures in female patients. The overall risk was 1/10 300 (14). A single-center study of 14 228 patients with epidural anesthesia found an incidence of epidural hematoma of 1/4741. Epidural hematomas were found only after lumbar puncture. However, none of the patients suffered long-term neurological damage (13). A publication from 2009 estimated the incidence of paraplegia or death after neuraxial block in the region of 0.7 to 1.8 per 100 000. Two third of paraplegias were transient (15). Conducting continuous epidural anesthetic procedures requires close neurological monitoring because early diagnosis and immediate treatment by means of laminectomy can prevent lasting neurological damage. Neurological complications after regional anesthesia were analyzed in a review of 32 publications from 1995 to 2005 (16). The review found an incidence of

**TABLE 2**

**Association between anesthesia-related deaths and age or patients' ASA status (adapted from [5])**

	Mortality/100 000 anesthesiological procedures	95% confidence interval
<b>Age</b>		
0–7 years	0.6	0.12–3.2
8–15 years	1.2	0.3–3.2
16–39 years	0.52	0.24–0.93
40–75 years	5.2	2.7–8.1
≥ 75 years	21	8.3–34
<b>ASA classification</b>		
ASA I	0.4	0.12–0.81
ASA II	5	1.6–9.1
ASA III	27	12–44
ASA IV	55	1.1–130

neuropathy after spinal anesthesia of 3.78/10 000 and for epidural anesthesia of 2.19/10 000. The proportion of persistent neurological problems for spinal anesthesia was 0 to 4.2 per 10 000 and for epidural anesthesia, 0 to 7.7 per 10 000.

The following risk factors were identified for the development of epidural hematomas:

- Intake of antithrombotic drugs
- Coagulopathies
- Female sex
- Age >50 years
- Orthopedic procedure
- Ankylosing spondylitis
- Renal failure
- Multiple punctures and catheter manipulations (17).

To reduce the risk of epidural hematomas, the guidelines for administering anticoagulants and regional anesthesia need to be strictly adhered to (18).

Transient neurological damage after peripheral nerve block is reported to have an incidence of 2.84/100 (interscalene block), 1.48/100 (axillary plexus block), and 0.34/100 (femoral nerve block) (16). In the 16 studies into neuropathic complications after peripheral nerve block, only one case of persistent neuropathy was reported.

Infectious complications are another risk of continuous catheter procedures. The risk ranges from mild local infections to epidural abscesses. In the context of the Network for the Safety of Regional Anaesthesia [sic] in Germany, initiated by the German Society of Anaesthesiology [sic] and Intensive Care Medicine (*Deutsche Gesellschaft für Anästhesiologie und Intensivmedizin*, DGAI) and the Professional Association of

German Anesthetists (*Berufsverband Deutscher Anästhesisten*, BDA), the incidence of infection was studied on the basis of the standardized documentation for a total of 8781 catheter procedures (22 112 catheter days) for regional anesthesia (19). Neuraxial procedures were performed in 5057 cases and 3724 cases were peripheral catheter procedures. In total, 4 severe, 15 moderate, and 128 mild infections were documented. Neuraxial procedures were found to be associated with a higher rate of infection than peripheral procedures (2.7% vs 1.3%). Further risk factors were:

- Multiple punctures of the skin versus single puncture (4.1% vs 1.6%)
- The catheter remained in situ for longer
- Poor patient condition.

Perioperative antibiotic prophylaxis or existing diabetes mellitus were not associated with an increase in the rate of infections.

## Anesthesia and outcome

Although we have shown that anesthesia-associated mortality is thankfully still very low, a study of 1064 patients found that the overall perioperative mortality within the first postoperative year is disturbingly high (20). The researchers found that after an operation under general anesthesia, 5.5% of all patients died within one year, and in patients older than 65 years this proportion rose to 10.3%. Death within the first year after an operation was mostly associated with patients' pre-existing comorbidities, but the cumulative duration of very deep anesthesia and intraoperative systolic blood pressure measurements of less than 80 mm Hg were found to be independent predictors for significantly raised mortality. As early as in 2003, the development of perioperative fast-track concepts drew attention to the fact that anesthesia has an important impact on patients' postoperative recovery (21). Postoperative need for treatment can be reduced by means of anesthesiological management as follows:

- Assuring intraoperative normothermia
- Adequate management of volume
- Providing analgesia
- Reducing posttraumatic stress reactions
- Enabling easier mobilization
- Reducing gastrointestinal atony
- Reducing postoperative nausea and vomiting

All these issues can be notably improved by combining thoracic epidural anesthesia/analgesia and general anesthesia. A retrospective data analysis of a cohort of 12 817 patients (Medicare data) found that such a combined anesthetic approach substantially reduced morbidity and mortality after colectomy. Without epidural anesthesia, mortality after 7 days was 26.79/1000, whereas with epidural anesthesia this rate reached only 9.3/1000 (OR 0.35, 95% confidence interval 0.21 to 0.59) (22).

## Initiatives to improve patient safety

In their editorial "To err is human," Hardman and Moppett wrote: "Errors are an inevitable part of anaesthetic [sic] practice. Anaesthetists [sic] are humans and



humans make errors" (e17). For these reasons, in spite of the continuing low mortality in the context of anesthesia, a need exists to further improve patient safety. One step in the right direction was taken with the adoption of the Helsinki Declaration on Patient Safety in Anesthesiology, which was written as a collaborative project by the European Board of Anaesthesiology (EBA) and the European Society of Anaesthesiology (ESA) (23). This declaration challenges all medical centers for anesthesiology to adopt a bundle of measures to optimize patient safety.

In addition, a particular focus should be on the further optimization of training in anesthesiology (e18). This includes not only specialty training leading to the qualification of anesthesiologist, but continuing safety training should also include simulator training (e19, e20). Furthermore, we wish to remind our readers of the "parallel anesthesia" judgments of the German Federal Court of Justice, which laid down legal minimum requirements and has drawn the conclusion that anesthesia should be administered only by an anesthesiologist who has undergone specialist training or by another physician—if that physician is reasonably advanced in his or her training—under the supervision of an anesthesiologist, with eye contact and verbal communication between the two as an absolute *sine qua non* (24).

## Conclusion

The optimization of perioperative processes, in which anesthesiology assumes a key role, has become increasingly important in the last few years. Recent studies have shown that anesthesiological management can have a relevant influence on patients' outcomes. Results from recent studies also indicate that anesthesiological therapy may have a relevant impact on a patient's immune function (25). In order to quantify this role in greater detail, further studies are needed, especially prospective studies with large case numbers. Additionally we can state that anesthesia-associated mortality in patients without relevant systemic disease continues to be low. However, the increasing numbers of elderly and multimorbid patients, who would have

been considered inoperable in the past and who nowadays are subjected to extended procedures that were unthinkable in the past, has meant that anesthesia-associated mortality has risen again in numerical terms.

## Conflict of Interest statement

PD Dr André Gottschalk has received honoraria for speaking from Baxter, B. Braun, and MSD. He was also a member of the advisory board of Baxter, on the subject of "continual wound infusions of local anesthetics." Professors Zenz, Standl, and Van Aken declare that no conflict of interest exists.

Manuscript received on 6 August 2010, revised version accepted on 25 November 2010.

Translated from the original German by Dr Birte Twisselmann.

## REFERENCES

- Macintosh RR: Deaths under anaesthetics. *Br J Anaesth* 1949; 21: 107–36.
- Eichhorn JH: Prevention of intraoperative anesthesia accidents and related severe injury through safety monitoring. *Anesthesiology*. 1989; 70: 572–7.
- Weiser TG, Regenbogen SE, Thompson KD, et al.: An estimation of the global volume of surgery: a modelling strategy based on available data. *Lancet* 2008; 372: 139–44.
- Li G, Warner M, Lang BH, Huang L, Sun LS: Epidemiology of anesthesia-related mortality in the United States, 1999–2005. *Anesthesiology* 2009; 110: 759–65.
- Lienhart A, Auroy Y, Pequignot F, et al.: Survey of anesthesia-related mortality in France. *Anesthesiology* 2006; 105: 1087–97.
- Newland MC, Ellis SJ, Lydiatt CA, et al.: Anesthetic-related cardiac arrest and its mortality: a report covering 72,959 anesthetics over 10 years from a US teaching hospital. *Anesthesiology* 2002; 97: 108–15.
- Arbous MS, Meursing AE, van Kleef JW, et al.: Impact of anesthesia management characteristics on severe morbidity and mortality. *Anesthesiology* 2005; 102: 257–68; quiz 491–2.
- McDonnell NJ, Paech MJ, Clavisi OM, Scott KL: Difficult and failed intubation in obstetric anaesthesia: an observational study of airway management and complications associated with general anaesthesia for caesarean section. *Int J Obstet Anesth* 2008; 17: 292–7.
- Paranjothy S, Griffiths JD, Gyte GM: Interventions at caesarean section for reducing the risk of aspiration pneumonia. *Cochrane Database Syst Rev*. 2010; Jan 20; (1): CD004943.
- Ghoneim MM, Block RI, Haffarnan M, Mathews MJ: Awareness during anesthesia: risk factors, causes and sequelae: a review of reported cases in the literature. *Anesth Analg* 2009; 108: 527–35.
- Bischoff P, Rundshagen I: Awareness during general anesthesia. *Dtsch Arztebl Int* 2011; 108(1–2): 1–7.
- Berg H, Roed J, Viby-Mogensen J, et al.: Residual neuromuscular block is a risk factor for postoperative pulmonary complications. A prospective, randomised, and blinded study of postoperative pulmonary complications after atracurium, vecuronium and pancuronium. *Acta Anaesthesiol Scand*. 1997; 41: 1095–103.
- Popping DM, Zahn PK, Van Aken HK, Dasch B, Boche R, Pogatzki-Zahn EM: Effectiveness and safety of postoperative pain management: a survey of 18 925 consecutive patients between 1998 and 2006 (2nd revision): a database analysis of prospectively raised data. *Br J Anaesth* 2008; 101: 832–40.
- Moen V, Dahlgren N, Irestedt L: Severe neurological complications after central neuraxial blockades in Sweden 1990–1999. *Anesthesiology* 2004; 101: 950–9.
- Cook TM, Counsell D, Wildsmith JA: Major complications of central neuraxial block: report on the Third National Audit Project of the Royal College of Anaesthetists. *Br J Anaesth* 2009; 102: 179–90.
- Brull R, McCartney CJ, Chan VW, El-Beheiry H: Neurological complications after regional anesthesia: contemporary estimates of risk. *Anesth Analg* 2007; 104: 965–74.

## KEY MESSAGES

- The introduction of safety standards and improved training has resulted in a reduction in anesthesia-associated mortality from 64/100 000 in the 1940s to 0.4/100 000 in the present.
- Owing to a disproportionate increase in the numbers of elderly and multimorbid patients and surgical procedures being carried out that would have been unthinkable in this group of patients in the past, anesthesia-related mortality has risen in numerical terms.
- The reason for this rise is, however, not a decrease in the quality of anesthesiological care.
- Adequate anesthesiological care can contribute to a notable reduction in the perioperative need for treatment.

17. Pogatzki-Zahn EM, Wenk M, Wassmann H, Heindel WL, Van Aken H: Complications of regional anesthesia: diagnostic and management. *Anesthesiol Intensivmed Notfallmed Schmerzther* 2007; 42: 42–52.
18. Gogarten W, Vandermeulen E, Van Aken H, Kozek S, Llaou J, Samama C: Regional Anesthesia and Antithrombotic/Antiplatelet Drugs Recommendations of the European Society of Anaesthesiology. *Eur J Anaesthesiol* 2010; 12: 999–1015.
19. Volk T, Engelhardt L, Spies C, et al.: Incidence of infection from catheter procedures for regional anesthesia: first results from the network of DGA and BDA. *Anaesthesist* 2009; 58: 1107–12.
20. Monk TG, Saini V, Weldon BC, Sigl JC: Anesthetic management and one-year mortality after noncardiac surgery. *Anesth Analg* 2005; 100: 4–10.
21. Kehlet H, Dahl JB: Anaesthesia, surgery, and challenges in post-operative recovery. *Lancet* 2003; 362: 1921–8.
22. Wu CL, Rowlingson AJ, Herbert R, Richman JM, Andrews RA, Fleisher LA: Correlation of postoperative epidural analgesia on morbidity and mortality after colectomy in Medicare patients. *J Clin Anesth* 2006; 18: 594–9.
23. Mellin-Olsen J, Staender S, Whitaker DK, Smith AF: The Helsinki Declaration on Patient Safety in Anaesthesiology. *Eur J Anaesthesiol* 2010; 27: 592–7.
24. Münsteraner Erklärung: Gemeinsame Stellungnahme des BDA und der DGA zur Parallelnarkose. *Anaesth Intensivmed* 2005; 46: 32–4.
25. Gottschalk A, Sharma S, Ford J, Durieux ME, Tiouririne M: Review article: the role of the perioperative period in recurrence after cancer surgery. *Anesth Analg* 2010; 110: 1636–43.

---

**Corresponding author**

PD Dr. med. André Gottschalk, MBA  
 Klinik für Anästhesiologie, Intensivmedizin und Schmerztherapie  
 Knappschafts Krankenhaus Bochum Langendreer  
 Universitätsklinikum der Ruhr Universität Bochum  
 In der Schornau 23–25  
 44892 Bochum, Germany

 For eReferences please refer to:  
[www.aerzteblatt-international.de/ref2711](http://www.aerzteblatt-international.de/ref2711)

REVIEW ARTICLE

# Is Anesthesia Dangerous?

André Gottschalk, Hugo Van Aken, Michael Zenz, Thomas Standl

## eReferences

- e1. Beecher HK, Todd DP: A study of the deaths associated with anesthesia and surgery: based on a study of 599, 548 anesthetics in ten institutions 1948–1952, inclusive. *Ann Surg* 1954; 140: 2–35.
- e2. Marx GF, Mateo CV, Orkin LR: Computer analysis of postanesthetic deaths. *Anesthesiology* 1973; 39: 54–8.
- e3. Dripps RD, Lamont A, Eckenhoﬀ JE: The role of anesthesia in surgical mortality. *JAMA* 1961; 178: 261–6.
- e4. Tiret L, Desmonts JM, Hatton F, Vourc'h G: Complications associated with anaesthesia—a prospective survey in France. *Can Anaesth Soc J* 1986; 33: 336–44.
- e5. Lunn JN, Devlin HB: Lessons from the confidential enquiry into perioperative deaths in three NHS regions. *Lancet* 1987; 2: 1384–6.
- e6. Kable AK, Gibberd RW, Spigelman AD: Adverse events in surgical patients in Australia. *Int J Qual Health Care* 2002; 14: 269–76.
- e7. Gawande AA, Thomas EJ, Zinner MJ, Brennan TA: The incidence and nature of surgical adverse events in Colorado and Utah in 1992. *Surgery* 1999; 126: 66–75.
- e8. Arbous MS, Grobbee DE, van Kleef JW, et al.: Mortality associated with anaesthesia: a qualitative analysis to identify risk factors. *Anaesthesia* 2001; 56: 1141–53.
- e9. Dindelli M, La Rosa M, Rossi R, et al.: Incidence and complications of the aspiration of gastric contents syndrome during cesarean section in general anesthesia. *Ann Ostet Ginecol Med Perinat* 1991; 112: 376–84.
- e10. Warner MA, Warner ME, Weber JG: Clinical significance of pulmonary aspiration during the perioperative period. *Anesthesiology* 1993; 78: 56–62.
- e11. Fasting S, Soreide E, Raeder JC: Changing preoperative fasting policies. Impact of a national consensus. *Acta Anaesthesiol Scand* 1998; 42: 1188–91.
- e12. Sebel PS, Bowdle TA, Ghoneim MM, et al.: The incidence of awareness during anesthesia: a multicenter United States study. *Anesth Analg* 2004; 99: 833–9.
- e13. Robins K, Lyons G: Intraoperative awareness during general anesthesia for cesarean delivery. *Anesth Analg* 2009; 109: 886–90.
- e14. Wu CL, Cohen SR, Richman JM, et al.: Efficacy of postoperative patient-controlled and continuous infusion epidural analgesia versus intravenous patient-controlled analgesia with opioids: a meta-analysis. *Anesthesiology*. 2005; 103: 1079–88; quiz 109–10.
- e15. Vandermeulen E, Gogarten W, Van Aken H: Risks and complications following peridural anesthesia. *Anaesthesist*. 1997; 46 (Suppl 3): 179–86.
- e16. Wulf H: Epidural anaesthesia and spinal haematoma. *Can J Anaesth* 1996; 43: 1260–71.
- e17. Hardman JG, Moppett IK: To err is human. *Br J Anaesth* 2010; 105: 1–3.
- e18. Staender SE: Patient safety in anesthesia. *Minerva Anesthesiol* 2010; 76: 45–50.
- e19. Cumin D, Weller JM, Henderson K, Merry AF: Standards for simulation in anaesthesia: creating confidence in the tools. *Br J Anaesth* 2010; 105: 45–51.
- e20. Boulet JR, Murray DJ: Simulation-based assessment in anesthesiology: requirements for practical implementation. *Anesthesiology* 2010; 112: 1041–52.